Association for Information Systems
AIS Electronic Library (AISeL)

AMCIS 2005 Proceedings

Americas Conference on Information Systems (AMCIS)

2005

Interface Design for Mobile Applications

Boonlit Adipat
University of Maryland - Baltimore County, badipat1@umbc.edu

Dongsong Zhang
University of Maryland, Baltimore County, zhangd@umbc.edu

Interface Design for Mobile Applications

Boonlit Adipat
University of Maryland Baltimore County
badipat1@umbc.edu

Dongsong Zhang
University of Maryland Baltimore County
zhangd@umbc.edu

ABSTRACT

Interface design is arguably one of the most important issues in the development of mobile applications. Mobile users often suffer from the poor interface design that seriously hinders the usability of those mobile applications. The major challenge in the interface design of mobile applications is caused by the unique features of mobile devices, such as small screen size, low resolution, and inefficient data entry methods. Therefore, there is a pressing need of theoretical frameworks or guidelines for designing effective and user-friendly interfaces for mobile applications. Based on a comprehensive literature review, this paper proposes a novel framework for the design of effective mobile interfaces. This framework consists of four major components, namely information presentation, data entry methods, mobile users, and context. We also provide a set of practical interface design guidelines and some insights into what factors should be taken into consideration while designing interfaces for mobile applications.

Keywords

Interface, user-centered design, mobile application, wireless environment

INTRODUCTION

Mobile handheld devices, including personal digital assistants (PDAs) and cell phones, have become popular tools in business and normal life routines. With a mobile device, a user can obtain universal information access at anytime and any location. There have been numerous emerging mobile applications that support users to conduct a variety of activities on their mobile devices (e.g., online shopping, Internet access, and retail management) (Nah, Siau and Sheng, 2005; Zhang, 2003). However, existing applications are still far from maturity regarding usability. They may not provide interfaces with ease-of-use that can help users easily accomplish a task at hand (Chan, Fang, Brzezinski, Zhou, Xu and Lam, 2002).

Mobile users are facing problems of 1) information overload – excessive information that causes difficulty of locating the desirable information on small screens, 2) limited memory of mobile devices – placing a burden on users to remember the meanings of commands/icons/labels, 3) navigation loss – confusion about choosing a path to reach a desired page, and 4) cumbersome input methods – small physical/soft keyboards that need high levels of attention and proficiency (Zhang, 2003). These problems can make users feel reluctant to use mobile applications and slow down the advance and adoption of mobile technology (Lee and Benbasat, 2003).

Designing effective interfaces for mobile applications involves several challenges posed by unique features of mobile devices and context of use (York and Pendharkar, 2004). With the compact size of devices, information presentation can be aesthetically unpleasant and difficult to read, thus demanding intensive cognitive effort from users. Data entry with mobile devices is difficult. Users who enter data using stylus and small physical or soft keyboards may reduce the input speed and increase errors. For the context of use (e.g., walking/sitting, dark/bright, quiet/noisy environments), since users can use the same mobile application in a variety of situations, users' interaction with mobile devices is generally distracted by other tasks (e.g., talking and walking) (York and Pendharkar, 2004).

Although both desktop and mobile applications can access the same sources of information, their purposes of use and characteristics of devices and environments are profoundly different. Traditional guidelines of user interface design for desktop computers may not be directly applicable to mobile applications. Therefore, it is essential to develop new frameworks or guidelines for designing effective interfaces for mobile applications. This paper aims to provide a generic framework for mobile interface design. It discusses several important design issues and introduces emerging technologies and approaches that appear to propel the design and development of effective and user-friendly interfaces for mobile applications. The rest of the paper is organized as follows. In the next section, we introduce some related work on the interface design for mobile applications. Then, a generic framework of mobile interface design is proposed. We highlight several important issues and present useful design guidelines in the framework. Finally, we conclude the paper with future research directions.

RELATED WORK

Researchers have suggested that context, content, and customization are the vital factors for designing successful interfaces of mobile applications (Lee and Benbasat, 2003; Tarasewich, 2003). Interfaces of mobile applications should function well regardless of the change of context; content presented on screen should be appealing to users by the use of multimedia content; and information presented on mobile devices should be customized to reduce information overload and to coordinate with the limitation of visual display.

We can categorize existing researches of mobile interface design into two categories: information presentation and data entry. For information presentation, some studies have investigated the issues of navigation structure, amount and format of content, and menu naming for small screens (Gong and Tarasewich, 2004; Jones, Buchanan and Thimbleby, 2002; Kärkkäinen and Laarni, 2002). Some guidelines have been suggested. For example, providing navigation structures can facilitate users to finish tasks with minimum interaction; a long list of choices shown on one screen should be avoided in order to minimize users' cognitive load; and menu choices should be clear enough with easily interpretable labels and be consistent throughout a navigation site.

There are three popular input modes for data entry, namely voice (using speech as an input), pen or stylus, and keyboard (pressing keys on a keyboard or a keypad) (Chang, Meng, Li and Fung, 2002; MacKenzie and Zhang, 1999). Since users can use mobile devices in various environments, mobile applications should be designed to utilize these input modes based on 1) tasks – for example, using keys/voice to enter text, using a pen to draw a picture; 2) physical devices (e.g., size and shape) – for example, voice/keys may be more suitable than pen for entering data into cell phones; and 3) environments – for example, pens/keyboards should be more appropriate to be used in a noisy environment than voice (Larson, 2003).

Another issue, user preferences, is also important to interface design for mobile applications but have been largely ignored so far. We suggest that mobile applications should provide user interfaces with effective content presentation and data entry methods also based on user characteristics and preferences. In this paper, we propose new design guidelines different from existing ones in two main aspects. First, we take both issues of data entry and adaptive information presentation into consideration. The paper will introduce several technical solutions and discuss their pros and cons. Second, we integrate user characteristics and preferences into the interface design for mobile applications.

A FRAMEWORK OF INTERFACE DESIGN FOR MOBILE APPLICATIONS

Built upon the past literature and our research, we propose a generic framework (Figure 1) that consists of four major components (i.e., user, context, information presentation, and data entry methods) that interface designers should take into consideration while designing interfaces of mobile applications.

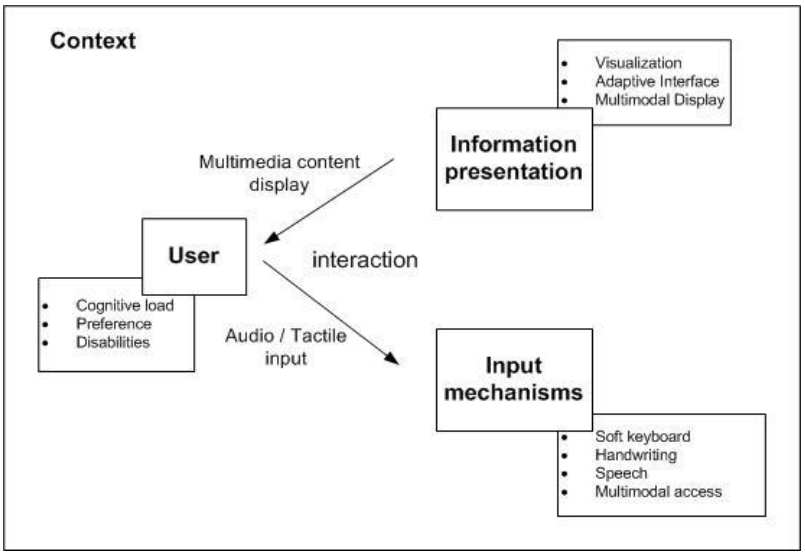

Figure 1. A framework of interface design for mobile applications

User

Interface designers need to remind themselves that the goal of creating an interface is to enable users to interact with applications easily. Because users have different preferences and characteristics, it is necessary to study what user characteristics are, in which information users are interested, and what is a preferred way to present the information. In this research, we focus on three major issues: cognitive load, preference, and disability, as shown in Figure 2.

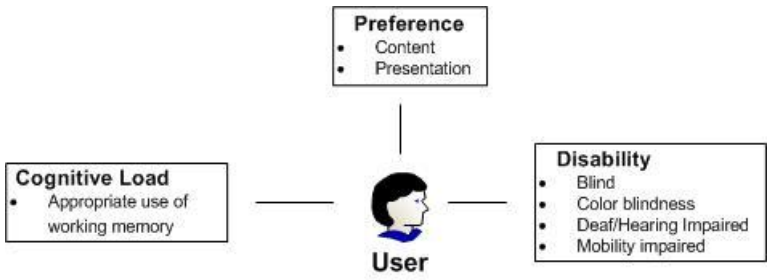

Figure 2. User characteristics and usability

User Preference

Users have different information needs and preferences on how information should be presented on mobile devices. They would like to obtain information of their interests displayed in a preferred format. For example, in terms of information interests, some users are interested in online shopping and would like to obtain discount or promotion information about clothes or electronics products, while other users are big fans of NBA and would like to receive latest scores of NBA games. For preferred formats, some users may prefer to view images or video clips in addition to text messages, although they may cause longer delay. However, other users may prefer to receive text messages only in order to shorten the downloading delay. Another example is that novice users may require step by step explanation of how to employ an application, but users who are familiar with the application may like to take shortcuts (only one or two pages of the application) in order to finish their tasks with minimal time.

We categorize user preferences into content and presentation preferences. Content preference includes topics of interest (e.g., information about stock indexes, latest news, the movie time, and meeting schedules). Presentation preference represents displaying styles or formats of information on mobile devices that individual users prefer (e.g., font size and media type). Table 1 shows how users' preference information can contribute to the interface design of mobile applications.

Preference	Purpose of use	Benefits
Content	• Remove irrelevant information that does not satisfy the needs of users; • Prioritize content to determine what should be presented as the focus of the screen at a time.	• Effectively use limited screen size to display relevant information (Quiroga, Crosby and Iding, 2004) ; • Reduce transmission delay and wireless network traffic (Samaras and Panayiotou, 2002); • Reduce time for users to locate information (Quiroga et al., 2004);
Presentation	• Display information in preferred styles and formats (e.g., color, font size/type, media objects).	• Increase user satisfaction (Zhang, 2003); • Increase possibility that mobile users might finish their tasks with minimal errors and time (Zhang, 2003).

Table 1. User preferences – purpose of use and benefits

Cognitive Load

Users have a limited capacity of working memory to process information and develop strategies to solve problems. The quality of the interface design increases if it allows users to spend the major part of their working memory on problem-solving, rather than on the interface itself (Mayer and Moreno, 2003). In mobile environments, reducing cognitive load of users is critical because mobile users normally perform multiple tasks while using mobile applications, such as finding the direction to a hospital from a city map displayed on a mobile device while driving. Besides, users tend to get distracted by the environmental changes. Therefore, interfaces of mobile applications should help users obtain information of interest without (or almost without) asking high visual attention and memory on the interfaces itself (e.g., memorizing positions of buttons and meanings of labels/icons). Table 2 shows cognitive overload problems and potential solutions that can be employed in the interface design of mobile applications.

Cognitive load problems	Interface design guidelines
Split attention effects: Users have to divide their attentions while performing multiple tasks simultaneously.	• Utilize audio or tactile (vibration) output in order to reduce the demand of visual attention to the mobile screen (Gong and Tarasewich, 2004); • Design interfaces that enable users to control applications via some attention-less mechanisms such as finger touch and speech input/output (Pham and Wong, 2004).
Information overload: Excessive information is presented at one time.	• Categorize information and present them in a hierarchical structure that users can drill down for more information if needed (Qiu, Zhang and Huang, 2004); • Put more important information closer to the top of the hierarchy (Kärkkäinen and Laarni, 2002); • Design interfaces to guide users to focus on a specific part of a screen at a time (Mayer and Moreno, 2003); • Provide search functions on the interface for locating objects easily (e.g., functions or information) within a page or entire applications (Jones et al., 2002).

Table 2. Cognitive load: problems and interface design guidelines

Disabilities

A challenging issue lies in exploring techniques to make mobile applications accessible and usable by people with physical problems (Shneiderman, 2000). Based on existing studies on mobile applications and some accessibility guidelines for desktop machines, we develop a set of mobile interface design guidelines for disabled users, as shown in Table 3.

Disabilities	Interface design guidelines
Blind	• Use audio and tactile modes to receive user input and present information (Caldwell, Chisholm, Vanderheiden and White, 2004); • Promptly provide audible confirmation every time users initiate a function (Chen, Chung, Lacsina and Tremaine, 2004); • Utilize some physical buttons to perform "Back", "Read input", and "Volume control" operations (Chen et al., 2004); • Provide functions to remind users of which position they are currently at (e.g., "You are in the address book program", "Select name") (Chen et al., 2004).
Color blind	• Do not rely on color; Use special font size or style (bold/Italic/underline) to convey information (e.g., using big font size for titles and important terms) (Caldwell et al., 2004); • Use black-and-white or very contrast colors (Caldwell et al., 2004); • Utilize user preference information to automatically adjust font/color (Richards and Hanson, 2004);
Deaf/hearing impaired	• Emphasize on visual display (e.g., text and image) (Caldwell et al., 2004); • Use tactile mode (vibration) to provide feedback or inform users of incoming messages.
Mobility impaired	• Design additional gadgets that are controllable by finger tips and connect them with mobile devices (Pham and Wong, 2004).

Table 3. Mobile interface design guidelines for disabled users

Context

Context can be defined as "any information that characterizes a situation related to the interaction between users, applications, and the surrounding environment" (Dey, Salber and Abowd, 2001, p. 100). It typically includes the location, identities of nearby people, objects, as well as environmental elements that may distract users' attention (e.g., noise, brightness or darkness of surrounding environments, and scene interruption). Context is a viable source of information for context-aware mobile applications – those that offer services and information according to the context. For example, a context-aware mobile information system may present information about nearby restaurants when a user drives by a neighborhood. Another example is a mobile application that can automatically enlarge the font size or increase the brightness of the screen in a dark environment for better readability.

Since the biggest advantage of mobile applications is universal information access, more and more context-aware mobile applications are emerging. There has not been comprehensive examination of how interfaces of context-aware mobile applications should be designed. We attempt to provide suggestions based on existing applications and problems that might occur in such applications, as shown in Table 4.

Context-aware interface design issues	Interface design guidelines
Perception of control: Users may feel loss of control while using context-aware services (e.g., automatic changing of font size/colors at night).	• Provide functions for users to turn on/off the services (Jameson, 2003); • Inform users before changing interface settings (Jameson, 2003; Stephanidis, Paramythis, Akoumianakis and Sfyrakis, 1998); • Inform users about receiving context information such as brightness intensity and noise level (Jameson, 2003).
User privacy: Users may feel annoyed by undesirable information (e.g., alert of discount or product advertisement when passing a mall) (Barkhuus and Dey, 2003).	• Provide context-aware information only when users need (Barkhuus and Dey, 2003); • Provide options for users to set priority of messages (Barkhuus and Dey, 2003); • Allow users to control visibility of interfaces generated by context-aware services (Barkhuus and Dey, 2003).

Table 4: Interface design guidelines for mobile context-aware applications

Information Presentation

Presenting a large volume of information on a small screen effectively to enable easy content navigation is a main problem faced by interface designers, who need to find a way to utilize the limited space efficiently. Without an effective strategy to manage the presentation of such information, users will experience problems in locating specific information, finding relationships among information presented on the screen, and understanding the information (Spence, 2001). There are different techniques that can be used to help present information in a more effective and adaptive manner, as shown in Figure 3.

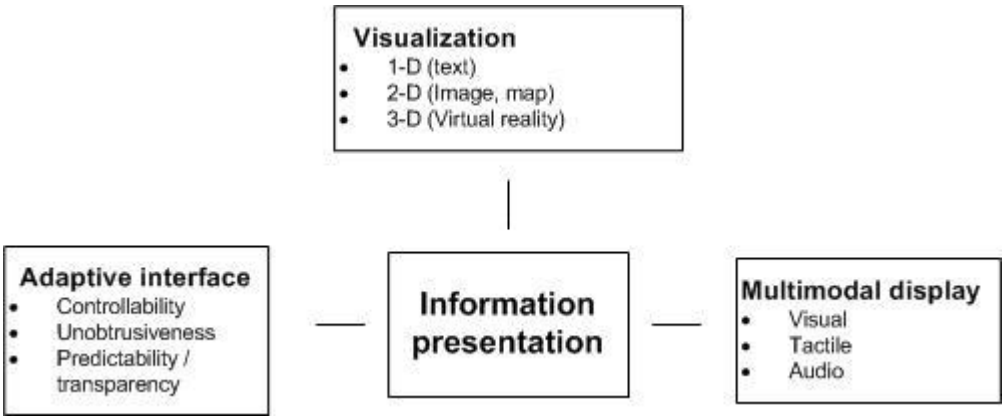

Figure 3. Information presentation techniques

Visualization

Visualization is an information presentation technique that utilizes advanced graphical presentation supported by computers to display data in meaningful and resourceful ways (Spence, 2001). Several techniques have been introduced to tackle the

problem of content presentation on mobile devices. We classify them into four categories: *presentation optimization, semantic conversion, zooming methods, and focus & context approaches*. These techniques can be applied either separately or in combination to provide effective information presentation on mobile devices.

Presentation optimization approaches adjust the width of displayed area and make a large amount of content fit in a small screen in real time. With a fixed horizontal width, mobile users can simply scroll up/down (while ignore left/right scrolling) to locate specific content. S*emantic conversion* converts original content into a smaller-sized version using text summarization techniques. In a summarization process, the original content is parsed and analyzed to extract important sentences based on linguistic and statistical rules, and can then be presented to users in a form of tree structure (Buyukkokten, Kaljuvee, Garcia-Molina, Paepcke and Winograd, 2002). *Zooming methods* rely on both structural and semantic information about content. At first, the hierarchical content structure plus a small set of semantic information are presented. A user can click any link to view more details of the original content (Qiu et al., 2004). *Focus & context* is a concept introduced to help interface designers find a way to manage large information using the idea of focus and context area to display the entire information. Users can view local information they are interested in (i.e., the focus) in details on a segment of the screen, while other peripheral information (i.e., the context) is also showed in the surrounding area with the reduced granularity of detail. This feature allows users to examine information without losing the full context (Spence, 2001). A typical example of this approach is the fisheye technique (Furnas, 1986), which has been applied to mobile applications such as mobile calendar (Bederson, Clamage, Czerwinski and Robertson, 2003).

We present interface design guidelines for information presentation by adopting the content dimension defined in the visualization taxonomy (Shneiderman, 1996) in the context of mobile applications. Based on this taxonomy, 1-dimensional content includes textual documents; 2-dimensional content includes images, maps and tables; and 3-dimensional content includes virtual reality[1] of real world objects.

Data type	Interface design guidelines
1-Dimensional	• Give an overview of entire content in a hierarchical structure (e.g., tree structure) (Buyukkokten et al., 2002); • Limit the depth of hierarchical menu structure, but expand the breath instead (Parush and Yuviler-Gavish, 2004); • Important content should be placed near the top of the hierarchy (Kärkkäinen and Laarni, 2002); • Use succinct and meaningful labels (Kärkkäinen and Laarni, 2002); • Use pop-up menu or transparent widget[2] to save screen space (Kamba et al., 1996); • Define a way to allow users to know where they are in a document or collection. (e.g. a pop-up menu that shows an overview of the entire content with a highlight of current position/page) (Spence, 2001); • Avoid horizontal scrolling (using presentation optimization techniques) (Jones, Marsden, Mohd-Nasir, Boone and Buchanan, 1999); • Design for shortest path to reach a destination page (Jones et al., 1999); • Use consistent buttons, layout, and menu naming for an entire application (Parush and Yuviler-Gavish, 2004); • Provide clear and meaningful error messages (Parush and Yuviler-Gavish, 2004); • Limit graphical content, text size, the use of forms/data entry fields, and the use of widgets (e.g., radio/icon-style buttons, forms) (Cotton and Commaford, 2005).
2- Dimensional	• Provide users an option to see an overview of information (Spence, 2001); • Use zooming techniques to drill down for more detailed information (Spence, 2001); • For a map scenario, provide directions (N,E,W,S). If an application has information of user location from a GPS, it should indicate where users are in the maps and provide direction users are heading to (Rakkolainen and Vainio, 2001); • Focus & context technique is useful (Bederson et al., 2003).
3- Dimensional	• Provide an overview of an entire object and users can choose to zoom in or out (Spence, 2001); • Provide flexible navigation functions (up, down, forward, backward).

Table 5. Interface design guidelines for information presentation based on the visualization taxonomy

[1] Virtual reality: the use of computer simulation to create 3-dimensional objects (Pham and Wong, 2004)

[2] Transparent menu that users can see the content while seeing menu options as a background (Kamba, Elson, Harpold, Stamper and Sukaviriya, 1996)

Adaptive Interface

An adaptive interface can be defined as an interface that dynamically reconfigures the presentation based on users' actions. The use of adaptive interfaces in mobile environments is beneficial to users from two perspectives: 1) providing additional information that is known to be of interest to specific users. For example, a system can automatically learn what specific information users are interested in based on the content users have previously requested/browsed or the patterns of their information access, then deliver newly obtained content that is very likely to be of users' interests; and 2) customizing presentation style and format according to user preferences and characteristics. For example, a system can select an appropriate medium (e.g., text, image, and sound) to present information based on user preferences (e.g., removing images and presenting only text messages to report the latest score of an NBA game, using big font size and plain background color for elderly users) (Stephanidis et al., 1998).

Jameson (2003) suggests three properties that a good adaptive interface should possess: controllability, predictability and transparency, and unobtrusiveness. Controllability refers to the degree to which users can control the occurrence of particular actions. Users should be the ones who make decisions on what a system has to do; Predictability refers to the degree to which users can predict what will happen after they perform certain actions. *Transparency* refers to the degree that users can understand system behavior or has a clear picture of how a system works. Unobtrusiveness refers to the degree to which users can concentrate on their tasks without (or almost without) demands of attention to interface (Jameson, 2003). Table 4 presents some guidelines that can achieve these objectives.

Adaptive interface properties	Interface design guidelines
Controllability	• Get users' approval before performing interface adaptation (Jameson, 2003); • Allow users to configure options to control adaptation behavior (Stephanidis et al., 1998).
Predictability / transparency	• Explain adaptation strategies to users and ask for their approval (Jameson, 2003); • Use consistent layout, menu naming, and informative feedback (Jameson, 2003).
Unobtrusiveness	• Utilize multimodal display based on changing context and user disabilities (Stephanidis et al., 1998); • Design input mechanisms that require minimal visual attention (e.g., speech inputs and key press) (Gong and Tarasewich, 2004).

Table 6. Interface design guidelines of adaptive interface for mobile devices

Multimodal Display

In a mobile environment, presenting information in various modality forms is beneficial due to the small size of mobile screen, which requires high visual attention from users, and the dynamic nature of the environment . We have identified three types of modality that can be used to present information on mobile devices: visual, audio, and tactile. We discuss appropriate conditions for employing each modality in Table 5.

Modality	Conditions of use
Visual	• Users have acute visual sense, especially for those who are deaf/hearing impaired (Caldwell et al., 2004); • Information consists of important image and graphic data that require visual attention.
Audio	• Users are obligated by other tasks at hand (e.g., driving) (Gong and Tarasewich, 2004); • Users are in environments that degrade their visual ability (e.g., dark room), especially for those who are visually or mobility impaired (Caldwell et al., 2004); • Users are not in noisy environment; • Information need is urgent and requires immediate response (Moyer, 2005).
Tactile	• Users are in the middle of a public event such as in a concert or meeting (Barkhuus and Dey, 2003); • Users are obligated by other tasks at hand (Pham and Wong, 2004); • Users prefers privacy (Barkhuus and Dey, 2003).

Table 7. Multimodal display and its conditions of use in mobile environments

Data entry methods

Providing inputs to small devices is difficult and requires a certain level of proficiency (Zhang, 2003). A number of innovative approaches (Table 8) have been proposed to alleviate the data entry problem. In this section, we introduce some data entry methods that are currently used in mobile applications.

A soft keyboard is a software component implemented with the touch screen technology, which displays a keyboard image on a mobile device and allows users to hit keys via a pen stylus for data entry as if it were a normal keyboard. The size, shape and the layout of a soft keyboard are adjustable to fit in screens of different mobile devices (MacKenzie and Soukoreff, 2002). A problem of using soft keyboards is that it requires high visual attention on the screen from users. Therefore, it is not suitable when users are performing other tasks or distracted by other activities.

The *Handwriting* input method is another commonly used data entry mechanism for mobile devices. It is based on handwriting recognition technology that imitates the natural human writing as input. A system extracts patterns of pen movement on the screen surface and interprets it as characters and words. Unistroke and Graffiti (Palm pilot) are examples of handwriting recognition systems used in mobile devices. Currently, techniques for handwriting recognition are still far from perfect. They still generate recognition errors and place burdens on users, requiring a clear writing pattern on mobile screen (MacKenzie and Soukoreff, 2002).

Voice input is another useful data entry mechanism for mobile devices. It is hands-free and can be used easily. Moreover, it is much faster than other input mechanisms. However, relatively low accuracy and high error rates of current voice recognition systems (Oviatt, 2000) remain a major problem and barrier of adopting this approach.

Multimodal access is a new data entry method for mobile devices. This technique allows mobile users to utilize multiple forms of input (i.e., voice, keypads, and stylus) to interact with a mobile device simultaneously. Multimodal access combines advantages of different data entry methods to help users improve interaction speed and accuracy. For example, speech and pen input can be combined to help users interact with a small object on a mobile screen (Oviatt, 2000). A recent study (Lai, 2004) shows that mobile users prefer mutimodal access than the unimodal access. In addition, speech input is identified as the dominant modality that users prefer for all tasks. Multimodal access is a promising method to enhance data entry performance for mobile applications.

Data entry methods	Conditions of use
Soft keyboard	• Users can pay sufficient visual attention to the mobile screen; • The mobile screen is large enough to display a soft keyboard.
Handwriting	• Users can pay visual attention to the mobile screen and handwritings have to be reasonably clear enough to be recognizable.
Voice	• Users can not give visual attention to mobile screens; • Privacy is not a major concern; • Users are neither in a noisy environment nor in a public area that may affect others.
Multimodal access	• Mobile devices are capable of receiving and processing multiple forms of input simultaneously.

Table 8. Data entry methods and their conditions of use in mobile environments

CONCLUSION

With the rapid advance of mobile technology and applications, a variety of mobile information systems have been developed and used. However, traditional interface design guidelines for desktop applications may not be directly applicable to mobile applications due to the unique features of mobile devices. The design of effective and adaptive interfaces for those mobile applications remains a key challenge, which can enhance usability and expedite the adoption of mobile applications. This drives a high demand for effective interface design guidelines and frameworks for mobile applications. This paper attempts to make a contribution to this field by introducing an innovative framework that incorporates four important perspectives, namely information presentation, data entry methods, user, and mobile context. We propose that interface designers should take them into consideration while designing an interface for a mobile application. We have discussed a number of design issues and enabling techniques related to each of those four perspectives. In addition, based on the proposed framework and findings from previous literature, we also provide some generic interface design guidelines. Even though it is difficult to address all possible issues of mobile interface design, this paper provides some insights that may help both practitioners and HCI researchers in designing and developing effective interfaces for mobile applications.

There are a number of interesting future research issues in this area such as mobile interface design for multimodal interaction in varying context, ultra-mobile devices, and private information. First, multimodal interaction (including both

multimodal access and display) paves a way of designing effective and user-friendly interfaces for mobile applications (Lai, 2004; Larson, 2003). However, the interface design becomes considerably more complex when we consider the issue of variable context. The questions place on which modality is appropriate to be employed for receiving input and presenting output in specific environments, and how interfaces should be designed to avoid users' confusion when different modalities are employed due to the change of context. Second, ultra-mobile devices (very small devices such as PDAs or cell phones at the size of wristwatch) with very small screens are emerging. Since current mobile interface design guidelines may not be applicable to these mobile devices, there is a pressing need to innovate new interface design techniques, such as using pixel-based visual notification cues (e.g., using color/brinking of LEDs to present information) (Tarasewich and Campbell, 2004). Third, privacy of personal information is an important issue that needs to be taken into consideration when designing interfaces of mobile applications. Due to the portability of mobile devices, there is a higher chance of disclosing sensitive information of users to strangers. Therefore, new methods for presenting private information are mandatory, such as using colors to convey messages and reducing amount of information displayed on mobile screens (Grimes and Tarasewich, 2005).

ACKNOWLEDGEMENTS

We want to thank Liwei Dai, Medha Umarji, and all reviewers for their helpful comments.

REFERENCES

1. Barkhuus, L. and Dey, A. (2003) Is context-aware computing taking control away from the user? Three levels of interactivity examined. *The 5th International Conference on Ubiquitous Computing (UBICOMP 2003)*, October 12-15, Seattle, Washington, 159-166.
2. Bederson, B. B., Clamage, A., Czerwinski, M. P. and Robertson, G. G. (2003) A fisheye calendar interface for PDAs: providing overviews for small displays. *CHI'03 extended abstracts on Human Factors in computing systems*, April 5-10, Ft. Lauderdale, FL, 618-619.
3. Buyukkokten, O., Kaljuvee, O., Garcia-Molina, H., Paepcke, A. and Winograd, T. (2002) Efficient Web Browsing on Handheld Devices Using Page and Form Summarization, *ACM Transactions on Information Systems, 20*,1, 82-115.
4. Caldwell, B., Chisholm, W., Vanderheiden, G. and White, J. (2004). Web Content Accessibility Guidelines 2.0, Retrieved Feb 23, 2005, from http://www.w3.org/TR/WCAG20/
5. Chan, S. S., Fang, X., Brzezinski, J., Zhou, Y., Xu, S. and Lam, J. (2002) Usability for Mobile Commerce across Multiple Form Factors, *Journal of Electronic Commerce Research, 3*,3, 187-199.
6. Chang, E., Meng, H., Li, Y.-C. and Fung, T.-y. (2002) Efficient Web Search on Mobile Devices with Multi-modal Input and Intelligent Text Summarization. *The Eleventh International World Wide Web Conference (WWW 2002)*, May 7-11, Honolulu, Hawaii, USA.
7. Chen, X., Chung, J.-w., Lacsina, P. and Tremaine, M. (2004) Mobile Browsable Information Access for the Visually Impaired. *Proceedings of the Tenth Americas Conferences on Information Systems*, NYC, New York, 3364-3374.
8. Cotton, J. and Commaford, P. (2005). Designing Web Content for Mobile Browsers, March 29, Retrieved May 4, 2005, from http://www-128.ibm.com/developerworks/wireless/library/wi-web/
9. Dey, A. K., Salber, D. and Abowd, G. D. (2001) A Conceptual Framework and a Toolkit for Supporting the Rapid Prototyping of Context-Aware Applications, *Human-Computer Interaction, 16*, 97-166.
10. Furnas, G. (1986) Generalized Fisheye Views. *Proceedings of the ACM CHI 86 Human Factors in Computing Systems Conference*, April 13-17, Boston, Massachusetts, 16-23.
11. Gong, J. and Tarasewich, P. (2004) Guidelines for Handheld Device Interface Design. *The 35th Annual Meeting of the Decision Science Institute (DSI 2004)*, November 20 - 23, Boston, Massachusetts, 3751-3576.
12. Grimes, A. and Tarasewich, P. (2005) Investigating Privacy-Augmented Displays for Mobile Devices. *Proceedings of HCI International 2005: 11th International Conference on Human-Computer Interaction*, June 22-27, Las Vegas, Nevada, forthcoming.
13. Jameson, A. (2003). Adaptive Interfaces and Agents. In J. Jacko and A. Sears (Eds.), *Human-Computer Interaction Handbook* (pp. 305-330). Mahwah: Erlbaum.
14. Jones, M., Buchanan, G. and Thimbleby, H. (2002) Sorting out Searching on Small Screen Devices. *Proceedings of the 4th International Symposium on Mobile HCI*, September 18-20, Pisa, Italy, 81-94.
15. Jones, M., Marsden, G., Mohd-Nasir, N., Boone, K. and Buchanan, G. (1999) Improving Web Interfaction on small displays, *Computer Networks, 31*, 1129-1137.
16. Kamba, T., Elson, S. A., Harpold, T., Stamper, T. and Sukaviriya, P. (1996) Using Small Screen Space More Efficiently. *Proceedings of the SIGCHI conference on Human factors in computing systems: common ground*, April 13-18, Vancouver, British Columbia, Canada, 383-390.

17. Kärkkäinen, L. and Laarni, J. (2002) Designing for small display screens, *Proceedings of the second Nordic conference on Human-computer interaction*, October 19-23, Aarhus, Denmark, 227-230.
18. Lai, J. (2004) Facilitating Mobile Communication with Multimodal Access to Email messages on a Cell Phone. *Proceedings of Conference on Human Factors in Computing Systems (CHI 2004) - Extened Abstracts*, April 24-29, Vienna, Austria, 1259-1262.
19. Larson, J. A. (2003). Commonsense Guidelines for Developing Multimodal User Interfaces, April 3, Retrieved May 4, 2005, from http://www.larson-tech.com/MMGuide.html
20. Lee, Y. E. and Benbasat, I. (2003). Interface Design for Mobile Commerce, *Communications of the ACM*, December, *46*, 49 - 52.
21. MacKenzie, I. S. and Soukoreff, R. W. (2002) Text Entry for Mobile Computing: Models and Methods, Theory and Practice, *Human Computer Interaction*, *17*,1-2, 141-147.
22. MacKenzie, I. S. and Zhang, S. X. (1999) The design and evaluation of a high performance soft keyboard. *Proceedings of the SIGCHI conference on Human factors in computing systems: the CHI is the limit (CHI'99)*, May 15-20, Pittsburgh, Pennsylvania, USA, 25 - 31.
23. Mayer, R. E. and Moreno, R. (2003) Nine Ways to Reduce Cognitive Load in Multimedia Learning, *EDUCATIONAL PSYCHOLOGIST*, *38*,1, 43-52.
24. Moyer, J. (2005). Human Factors Design Guidelines for ATIS/CVO, Chapter 19: Background of these human factors design guidelines for ATS/CO, Retrieved Febuary 23, 2005, from http://www.fhwa.dot.gov/tfhrc/safety/pubs/atis/ch19/body_ch19_03.html
25. Nah, F. F.-H., Siau, K. and Sheng, H. (2005). The VALUE of Mobile Applications: A Utility Company Study, *Communications of the ACM*, *48*, 85-90.
26. Oviatt, S. (2000) Multimodal system processing in mobile environments. *Proceedings of the 13th annual ACM symposium on User interface software and technology*, November 6-8, San Diego, California, USA, 21-30.
27. Parush, A. and Yuviler-Gavish, N. (2004) Web navigation structures in cellular phones: the depth/breadth trade-off issue, *International Journal of Human-Computer Studies*, *60*, 753-770.
28. Pham, B. and Wong, O. (2004) Handheld Devices for Applications Using Dynamic Multimedia Data. *Proceedings of the 2nd international conference on Computer graphics and interactive techniques in Australasia and South East Asia*, June 15-18, Singapore, 123-130.
29. Qiu, M. K., Zhang, K. and Huang, M. (2004) An Empirical Study of Web Interface Design on Small Display Devices. *Proceedings of 2004 IEEE/WIC/ACM International Conference on Web Intelligence*, September 20-24, Beijing, China, 29-35.
30. Quiroga, L. M., Crosby, M. E. and Iding, M. K. (2004) Reducing Cognitive Load. *Proceedings of the 37th Hawaii International Conference on System Sciences 2004*, Jan 5-8, Hawaii, 131-139.
31. Rakkolainen, I. and Vainio, T. (2001) A 3D City Info for mobile users, *Computers and Graphics*, *25*, 619-625.
32. Richards, J. T. and Hanson, V. L. (2004) Web Accessibility: A Broader View. *Proceedings of the Thirteenth International ACM World Wide Web Conference (WWW2004)*, May 17-24, NYC, New York, USA, 72 - 79.
33. Samaras, G. and Panayiotou, C. (2002) Personalized Portals for the Wireless User Based on Mobile Agents. *Proceedings of the 2nd International Workshop on Mobile Commerce*, September 28, Atlanta, GA, 70-74.
34. Shneiderman, B. (1996) The Eyes Have It: A Task by Data Type Taxonomy for Information Visualizations. *Proceedings of the IEEE Symposium on Visual Languages.*, September 3-6, Washington, DC, 336--343.
35. Shneiderman, B. (2000) Universal Usability, *Communications of the ACM*, May, *43*, 84-91.
36. Spence, R. (2001) Information Visualization, Addison-Wesley.
37. Stephanidis, C., Paramythis, A., Akoumianakis, D. and Sfyrakis, M. (1998) Self-Adapting Web-based Systems: Towards Universal Accessibility. *4th ERCIM Workshop on "User Interfaces for All"*, October 19-21, Stockholm, Sweden, 17-34.
38. Tarasewich, P.(2003) Designing Mobile Commerce Applications,*Communications of the ACM*, December,*46*,57-60.
39. Tarasewich, P. and Campbell, C. (2004) What Can You Say With Three Pixels? *Proceedings of MOBILE HCI 2004: 6th International Conference on Human Computer Interaction with Mobile Devices and Services*, September 13-16, Glasgow, Scottland, 1-12.
40. York, J. and Pendharkar, P. C. (2004) Human-computer interaction issues for mobile computing in a variable work context, *International Journal of Human-Computer Studies*, *60*, 771-797.
41. Zhang, D. (2003) Delivery of personalized and adaptive content to mobile devices: a framework and enabling technology, *Communications of AIS*, *12*, 183-202.